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13	08		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
This process will automatically inspect flimsies, panels, and completed boards measuring line spacing, widths, and flaws. The cell will incorporate robotic technologies. Nineteen cameras will digitize the inspection boards dimensions for comparison with a dimension and measurement data base. Keywords: Printed circuit boards; Inspection automation. (edc)

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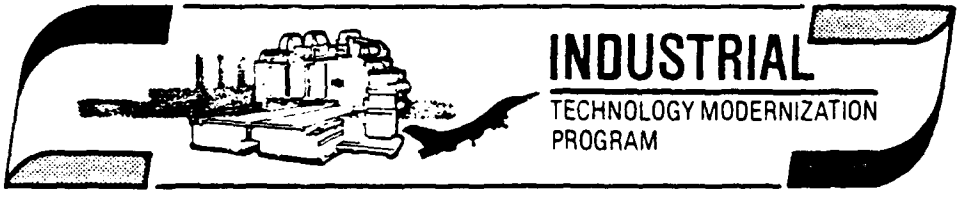
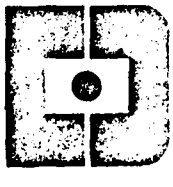
INDUSTRIAL TECHNOLOGY MODERNIZATION

Phase II Final Report
Project 8
PWB Inspection



Prepared for
GENERAL DYNAMICS
Fort Worth, Texas

Contract No. F33657-82-C-2034



Delco Systems Operations

DELCO ELECTRONICS CORPORATION
Goleta, California 93117

INDUSTRIAL TECHNOLOGY MODERNIZATION

PHASE II FINAL REPORT

PROJECT #8

PWB INSPECTION

CONTRACT No. F33657-82-C-2034

January 9, 1987

REV A

prepared for

GENERAL DYNAMICS

Fort Worth, Texas

by

Delco System's Operations

Goleta, California

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ILLUSTRATIONS

Industrial Technical Modernization Project #8

Final Report

I. General Introduction

Equipment for Delco's Industrial Technology Modernization Project 8, PWB Inspection, has been received from AOI Inc and is presently waiting for final installation. The projected startup date for the system is set for July 1, 1987. It is anticipated that approximately six to nine months will be required for the equipment to reach 100% operating capacity due to programming requirements and operator familiarity.

A Comparision of Present and Proposed Methods

Present

Printed wire board inspection is presently accomplished using human operators to visually verify circuit trace integrity. Inspectors are located in a typical inspection environment (lab benches) and primarialy use illuminated magnifiers to inspect for circuit trace shorts, opens and general workmanship. Inspection time depends on procuct line complexity, but in general takes approximately 30-45 minutes. Circuit card assemblies average eight layers (PWB's) and typically require 100% inspection prior to bonding to minimize follow-on rework or scrapping. Manpower requirements vary depending on build schedules, however, two to three operators are generally employed full time to accomplish this task. During peak periods additional inspectors are used on a temporary basis.

Proposed

The proposed method of printed wire board inspection will utilize automated machine vision tehcnology. The system will capture an image of a PWB and compare it to a preprogrammed image in memory. This not only allows the system to look for shorts and opens, but also to verify circuit trace presense/absense and widths. Typical inspection time would be under 5 minutes. It is envisioned that only one or two operators will be required to feed printed wire boards into the system or accomplish required programming.

Statement of Objective

PURPOSE

The purpose of the PWB Automatic Inspection Machine is to provide visual inspection capability with a 0% defect escape rate. In addition to providing higher yields with defects detected earlier in the fabrication flow, the results of this inspection will be used to help understand, improve and control the processes.

GENERAL REQUIREMENTS

1. The annual production of PWB's to be screened by the PWB Automatic Inpection Machine is anticipated to be 50,000-100,000 units.

2. The PWB Automatic Inspection Machine must be capable of meeting the mechanical and visual inspection requirements of Delco Electronics Specifications ES-9368 and ES-11663, Electro-Motive Division Specifications 234 and 2350, and MIL-P-55110C.

3. The PWB Automatic Inspection Machine must be capable of inspecting Artwork, Panels and completed PWB's. (Double Sided, Multi-Layer and Double-Double-Sided PWB's)

4. The PWB Automatic Inspection Machine must be automated using robotic techniques for all handling of material. This shall include loading items to be inspected and unloading items after inspection.

5. The PWB Automatic Inspection Machine must be capable of inspecting items at a rate of between one and two minutes per side. (Compared to the human inspector who might take 30-45 min per panel)

6. The PWB Automatic Inspection Machine must have an Edit-out capability for areas such as alpha-numerics, which violate the design rules, and therefore must be ignored.

7. The System must have the capability of inspecting panels up to a size of 24" x 24".

8. The System must be compatible with Plant Host Computer Systems, including VMS/VAX, CAD, MCS and IBM.

9. The System should be Software oriented, Menu driven and operator friendly.

10. Inspection operation should be initiated by inputing the Part Number of the item to be inspected or through use of Bar Codes on the part using a Bar Code reader.

INSPECTION BY DESIGN RULES

The PWB Automatic Inspection Machine shall be capable of the following:

1. Identify the Serial Number of the item to be inspected by use of a Bar Code reader.

2. Taking measurements of individual parameters and storing this data.

3. Identifying defect locations by X-Y coordinates.

4. Identifying defect data to PWB or Panel inspected.

5. Providing a printed output of inspection results.

6. Providing a means of stepping through listed defects, displaying an enlargement of the defect on a TV Monitor

7. Driving an X-Y Plotter Station to be used for Verification/Repair of Repairable items.

MEASUREMENTS

Measurements to be taken are of the following dimensional magnitude:

1. The minimum Conductor Width to be measured will be 0.003".

2. The minimum Conductor Spacing to be measured will be 0.004".

3. Terminal Areas will be 0.027" x 0.047" Minimum.

4. Annular Rings minimum size will be 0.002" to 0.010".

5. Hole sizes of 0.006" to 0.080". (Some non-plated holes as large as 0.250")

Undercutting of conductors shall not exceed the thickness of the copper clad and the plated copper.

SURFACE TREATMENTS

Inspection must be possible with item surfaces such as those:

1. Treated with oxides.

2. Etch roughened.

3. Tin-Lead plated.

4. Tin-Lead reflowed.

5. Other types of plating material.

FLAW DETECTION

The following types of flaws must be detectable:

1. Cracks and Voids

2. Open and Short Circuits.

3. Pin Holes.

4. Nodules/Spurs.

5. Notches/Mousebites.

6. Spurious Copper.

7. Hole Breakout.

SYSTEM OUTPUTS

The following outputs must be available as a result of data manipulation:

1. Statistical Analysis using accumulated data.

2. Trend Charts (X Bar & R).

3. Defect Summaries & Trend Reports.

4. Feedback for Process Control.

5. Sort of inspected hardware based on types and magnitudes of flaws detected.

6. Payroll information based on quantities of accepted items.

II Technical Approach Followed

To provide potential suppliers with detailed requirements, a Statement of Work was prepared. The SOW was submitted to each of four suppliers with a Request for Quotation. The Statement of Work is contained herein in its entirety.

STATEMENT OF WORK

1.0 SCOPE

This Statement of Work and associated attachments establish the requirements for procurement of an Automatic Printed Wiring Board Inspection Machine.

2.0 APPLICABLE DOCUMENTS

2.1 General Motors Corporation

GM Basic Electrical Standards for Industrial Equipment, dated April, 1980, and related supplements.

GM Sound Level Specification, dated February, 1979.

GM Fluid Power Standards, dated September, 1970.

2.2 Delco Electronics

Delco Electronics Specifications for Industrial Equipment, dated April, 1984.

Exceptions to this document applicable to this Work Statement are as follows:

Para. 17.1.1 - Shipping instructions to be obtained from Marv Friebert by calling (414) 768-2953.

Para. 18.1.1 - The approving authority at Delco Electronics, Milwaukee is the Work Statement originator. All approval prints, final drawings, or reproducibles, requests for deviation and questions concerning this specification shall be addressed to:

Delco Electronics Division
7929 South Howell Avenue
Oak Creek, Wisconsin 53154

ATTENTION: Mr. R. W. Ladd or
Mr. B. F. Sibley
Mail Station 2A13

TELEPHONE: (414) 768-2542

Para. 20.2.1 - Delete reference to requirements of Indiana Law (IC 1971, 22-8-1.1 et. seq.)

On page 38 under 'PROGRAMMABLE CONTROLLERS' delete Modicon.

2.3 Occupational Safety and Health Act dated 18 October 1972, Part 1910. 219. Mechanical Power Transmission apparatus.

2.4 Attachments to this Statement of Work:

Attachment 1. Requirements for an Automatic Printed Wiring Board Inspection Machine.

3.0 ARTICLES AND SERVICES TO BE SUPPLIED BY THE CONTRACTOR

3.1 Equipment

a. Design

b. Fabrication

c. Delivery

3.2 Engineering Data

a. Layout Drawings

b. Final Drawings

c. Specifications

d. Operating & Maintenance Manuals

e. Recommended Spare Parts List

f. Installation Instructions

g. Operating Software

3.3 Progress Information

3.4 Training

3.5 Quality Assurance Provisions

3.6 Warranty

3.7 Installation & Checkout Surveillance

4.0 DESCRIPTION OF ARTICLES & SERVICES

4.1 Equipment

4.1.1 Design - The Subcontractor shall execute all new design and the necessary modification to existing design to meet the requirements of the Attachments to this Statement of Work. Should the Subcontractor have an engineering standard practice on this design which conflicts with this Statement of Work, he may submit this standard provided he states in detail the variance from this Statement of Work in his quotation. If no exceptions are stated in the quotation, Delco Electronics will require the Subcontractor to fulfill all details of this Statement of Work.

4.1.2 Fabrication - The Subcontractor shall fabricate the Automatic Printed Wiring Board Inspection Machine per the requirements of Attachment #1 to this Statement of Work.

4.1.3 Delivery - The Subcontractor shall be responsible for the packaging and safe delivery of the Automatic Printed Wiring Board Inspection Machine to Delco Electronics.

4.1.4 The Subcontractor shall act in an advisory capacity during the installation and checkout of the equipment at Delco Electronics.

4.1.5 Milestone Chart and anticipated machine implementation schedule

a.	Release this S.O.W.	
b.	Vendor Quotation response	
c.	Delco Technical Review & Vendor selection.	
d.	Release Purchase Order	Start
e.	Preliminary Design Review	2 Mo's after P.O.
f.	Final Design Review	4 Mo's after P.O.
g.	Fabrication and Assembly	8 Mo's after P.O.
h.	Preliminary Acceptance @ Vendor facility	9 Mo's after P.O.
i.	Installation and checkout @ Delco	10 Mo's after P.O.
j.	Final Acceptance @ Delco	11 Mo's after P.O.

4.2 Engineering Data

4.2.1 Drawings outlining the Automatic Printed Wiring Board Inspection Machine showing approximate dimensions, weight, mounting points and requirements for accessibility, operation and maintenance

4.2.2 One reproducible electrical and pneumatic schematic, block diagram, and wiring diagram showing selected components and connector pinout

4.2.3 Final Drawings - One set of reproducibile and one set of non-reproducible drawings of the Automatic Printed Wiring Board Inspection Machine shall include the following information as a minimum.

a. Parts List - including generic part numbers where applicable

b. Electrical, pneumatic and hydraulic schematics

c. Cable and wire list.

d. Modifications made to purchased commercial equipment.

e. Assemblies, subassemblies, details & system interface.

All drawings and manuals will be the property of Delco Electronics for Maintenance, Repair and Servicing. Drawings will not be used to duplicate this machine.

4.2.4 Operation and Maintenance Manuals - The Subcontractor shall generate and submit two copies to Delco Electronics of an OPERATION AND MAINTENANCE MANUAL which shall be suitable for use by skilled technical level personnel in the repair, maintenance and the operation of the Automatic Printed Wiring Board Inspection Machine.

The MAINTENANCE MANUAL shall contain sufficient information to permit servicing down to the component level. Standard Maintenance Manuals on unmodified commercially available equipment is adequate.

4.2.5 Spare Parts List - The Subcontractor shall submit one list of recommended spare parts. Quantities listed shall be sufficient to support one piece of equipment for one year.

4.2.6 Installation Instructions - The Subcontractor shall submit installation drawings defining utilities and special installation requirements.

4.3 Training

Training of Technician skill level personnel, for two people at the Contractor's facility, shall be quoted separately at or near the time of acceptance.

4.4 Quality Assurance Provisions

4.4.1 Notification of Readiness for Acceptance - The Subcontractor shall notify Delco Electronics of the readiness of the Automatic Printed Wiring Board Inspection Machine for acceptance. This notification shall be given at least one (1) week before the scheduled acceptance start date. Notice of cancellation or change of an acceptance date shall be given at least three (3) days in advance of any scheduled acceptance date.

4.4.2 Preliminary Acceptance - Preliminary acceptance of the Automatic Printed Wiring Board Inspection Machine shall be accomplished at the Subcontractors facility. A functional demonstration in compliance with the requirements of this Statement of Work shall be conducted in the presence of the authorized Delco Electronics representatives.

Acceptance shall be based on both hardware compliance and machine performance.

4.4.3 Final Acceptance - Final acceptance of the Automatic Printed Wiring Board Inspection Machine shall be accomplished at Delco Electronics and shall be based on demonstration of compliance with the requirements of this Statement of Work. A final acceptance shall be conducted in the presence of authorized Delco Electronics representatives. Acceptance shall be based on both hardware compliance and machine performance.

4.4.4 Equipment Verification - The Subcontractor shall maintain technical liaison with Delco Electronics to correct deficiencies and/or to effect improvements in the operation and design of the equipment during the warranty period.

5.0 SUGGESTED METHOD FOR ANSWERING THIS STATEMENT OF WORK

5.1 Indicate either compliance or deviation and alternate specification in response, as required, to all numbers of this Work Statement and Attachments thereto. Follow this same procedure on the G.M. Electrical Standards.

5.2 Provide a breakdown of costs as follows, in answering this Statement of Work:

5.2.1 Non-recurring Costs - Engineering, design, drafting, software, operating manuals, service manuals, first copy equipment verification (liaison) and first copy checkout support.

5.2.2 Recurring Costs - Fabrication and material.

5.2.3 Training - Quote training of Delco personnel as a separate cost item.

6.0 MAILING INSTRUCTIONS

The mailing address for documentation, reports and notices shall be as follows:

Delco Electronics Division
General Motors Corporation
P.O. Box 471
Milwaukee, Wisconsin 53201

ATTENTION: Mr. J. Lukomski
Purchasing
Dept 417, M/S 1A09

CC: Mr. R. W. Ladd (2 Copies)
Quality Engineering
Dept 474, M/S 2A13

ATTACHMENT I

AUTOMATIC PRINTED WIRING BOARD INSPECTION CELL

ITM PROJECT 8

TABLE OF CONTENTS

1.0 SCOPE

1.1 PURPOSE

This document outlines the equipment requirements for an Automatic Printed Wiring Board Inspection Machine to be used for the inspection of fabricated Printed Wiring Board layers, artwork, and laminated printed wiring boards.

1.2 DOCUMENTS

The following government standards, specifications, and regulations, issues in effect on the date of this contract, or as otherwise stated herein, shall form a part of this statement of work to the extent specified.

Sound Level Specification	GM Spec SL1.0
Robotic Safety Standards	Section 28
Basic Electrical Standard	ES1
GM Manufacturing Automation Protocol	(Based on Availability)

2.0 DESCRIPTION OF ARTICLES AND SERVICES TO BE FURNISHED

2.1 GENERAL

2.1.1 SYSTEM OBJECTIVES

2.1.1.1 The Automatic Printed Wiring Board Inspection Machine will use automatic vision and robotic systems to visually inspect a PWB Inner Layer for proper line widths and line spacing, pad sizes and annular ring dimensions, as well as providing positive detection of configuration departures such as open and shorted conductors, conductor width and spacing below minimums, locally reduced conductor width, cracks and voids, spurious copper and mousebites.

2.1.1.2 The Automatic Printed Wiring Board Inspection Machine shall be capable of inspecting various types of product including but not necessarily limited to the following:

a. Artwork - Silver Halide, positive or negative transparencies, Diazo, Glass

b. Inner Layers - Etched Copper, Photoresist on Copper

c. PWB's - Etched Copper, Tin-lead plating, reflowed tin-lead

2.1.1.3 The inspection cell shall consist of 1) an inspection station to be used for the actual inspection of the product; 2) a material handling robotic system to automatically load and unload the inspection machine; 3) A primary computer controller; 4) an off-line manual verification station; 5) a Bar Code label machine to identify defective parts; and 6) a safety system.

2.1.1.4 Part fixturing requirements shall be semi-dedicated, allowing for common usage between several classes of parts to be inspected. All fixturing shall be loaded and unloaded using robots. Detailed fixturing requirements shall be developed during the final systems development.

2.1.1.5 The Inspection Cell System shall provide interface through an entry keyboard which will allow the user to define acceptance criteria for individual part number identification through menu selection of design rules. Acceptance criteria shall have restricted access. The operator of the system shall only have access to hard copy printouts of inspection results, plus the option of statistical quality and process trend information.

2.1.2 INSPECTION CELL SUBSYSTEMS DEFINITION

The Automatic Printed Wiring Board Inspection Machine System shall consist of:

a. Inspection Station
b. Material Handling Robotics System
c. Primary Computer System with keyboard, monitor and printer
d. Manual Verification Station
e. Bar Code reader
f. Safety System
g. Thermal Printer

2.1.2.1 INSPECTION STATION

2.1.2.1.1 The Inspection Station shall be capable of meeting the mechanical and visual inspection requirements of Delco Electronics Engineering Specifications ES-9368 and ES-11663, as well as meeting the requirements of MIL-P-55110C.

2.1.2.1.2 Printed wiring board flimsies, multilayer panels, and completed boards of all types will be presented to the machine for inspection. In addition, the machine will be utilized for periodic inspection of artwork photo-tools.

2.1.2.2 MATERIAL HANDLING ROBOT(S)

2.1.2.2.1 A material handling robot system shall be designed into the inspection cell to accomodate the transfer of parts from a transport container to the inspection machine, to turn the part over for inspection of the reverse side, and to remove the part to another transport container.

2.1.2.2.2 The material handling system, in concert with the central controller, shall be capable of placing the unloaded parts in different transport containers, determined by the results of the inspection performed. The system should be programmable such that parts with no reported defects can be off-loaded to one location while parts with defects can be off-loaded to a different location.

2.1.2.3 PRIMARY COMPUTER

2.1.2.3.1 The primary computer shall control all of the activities of the overall work cell including the bar code reader, robotics controls, visiion system controls, material handlers, servo-mechanical controls and statistical process controls. For this reason, it is necessary that the primary computer runs under a Unix-like, real-time, multi-tasking operating system such as GNX or XENIX. The preferred computer for this work cell control is an IBM PC/AT. The preferred programming language for software development within the primary computer is the "C" language, for the purpose of uniformity with other Delco Electronics automated work cells, portability between various CPU's and the general flexibility provided by this language.

2.1.2.3.2 The primary computer system utilized with this inspection cell shall be compatible with and designed to interact with the present plant computer systems (Digital Equipment Corporation VAX or PDP 11730). The inspection cell must be capable of providing data outputs to the plant system dealing with acceptable and reject hardware quantities on a part number/lot by part number/lot basis.

2.1.2.3.3 The system printer is used for printing out Design Rules, individual piece part inspection results and/or lot results, including Statistical Analysis presentations.

2.1.2.3.4 The dictionary of defect codes defined by Delco Electronics for Quality Trend Reporting shall be incorporated into the primary computer system software.

2.1.2.4 MANUAL VERIFICATION STATION

2.1.2.4.1 The Manual Verification Station shall include an X-Y table which can be driven by the primary computer system, downloaded from a VAX central computer system or a disc drive loaded with the defect coordinate data. The operator should be able to view the inspection results by manually stepping through the defects.

2.1.2.4.2 The Manual Verification Station shall be capable of presenting a magnified video image of the detected defect to the operator and will include a 10X microscope to be used for repair activity.

2.1.2.4.3 The Keyboard and monitor shall be linked with software which provides a menu driven, operator friendly type of operation.

2.1.2.4.4 The data storage system must be capable of accepting the results of the activity performed at the Manual Verification Station, i.e., determination that defect was a false alarm, changes in defect classification, rework performed, disposition of product as acceptable or scrap. This data will then be available in periodic inspection reports.

2.1.2.5 BAR CODE READER

2.1.2.5.1 Defective product as determined by the Automatic Printed Wiring Board Inspection Machine must be identified by coding which relates to the stored defect detail information within the system. An Automatic Bar Code Label attachment shall be provided which will apply a sequentially numbered label to any product item which has reported defects. The labels must be removed from the product prior to lamination.

2.1.2.5.2 The Bar Code label will be keyed to a sequential numbering system within the primary computer software system, thereby enabling the operator to recover defect information applicable to a given item

2.1.2.6 SAFETY SYSTEM

2.1.2.6.1 The inspection cell shall have a safety system that will automatically shut down all operations in areas accessible by operating robots when entered by any person. Alarm annunciators shall be provided to indicate the occurrence of a safety violation. A plexiglass perimeter shield is prefer able to a light beam system.

2.1.2.6.2 A flashing indicator light will be on when the system is operating.

2.1.2.7 THERMAL PRINTER

2.1.2.7.1 A thermal printer shall be provided for the purpose of providing a permanent record of observed defects if desired.

2.1.2.7.2 The printer shall be capable of reproducing the image present on the TV Monitor display screen.

2.1.3 SEQUENCE OF OPERATIONS

During the initial development phase it will be acceptable for parts to be manually loaded into fixtures or to the station. A typical sequence of operations is summarized herein.

2.1.3.1 Operator types Part number of lot of parts to be inspected. (This presumes that design rules have already been loaded by Quality Engineering.) The design rules are downloaded into memory from the central database computer but should also reside on disk storage within the inspection machine primary computer system.

2.1.3.2 First part is loaded into machine and inspection sequence is initiated.

2.1.3.3 After the first side of the part has been inspected, the inspection sequence for the second side will be initiated.

2.1.3.4 The physical order of the pieces being inspected must be maintained throughout the two inspection cycles. Bar Code labels must be applied to each piece that is indicated as defective. The label must carry the part number of the part as well as an arbitrary (or real) serial number identification.

2.1.3.5 The defective items will be routed to the Manual Verification/Repair station for final disposition.

2.1.3.6 After inspection is complete, all data shall be transferred from the controller to the primary computer and an inspection report for the lot will be generated, identifying all discrepancies and providing statistical information pertaining to that lot. The quality data will also be sent to the VAX or PDP 11730 for further processing.

2.1.4 SYSTEM CYCLE TIME AND THROUGHPUT

The system must be capable of maintaining a throughput time for a standard multi-layer inner layer panel (as used in preliminary tests) of less than one (1) minute per side.

2.1.5 EXPANSION CAPABILITY

2.1.5.1 The inspection system shall be designed to include an expansion capability. This expansion shall be accomplished through the addition of additional inspection machines linked to the same central computer and/or through expansion of the system software.

2.1.5.2 The inspection system shall be capable of receiving operational data from an intraplant network and returning measurement data to that network. The electrical standard shall be IEEE-802 token passing bus or as a minimum, RS-232. The protocol shall be the GM MAP standard which is based on current ISO, IEEE and NBS standards for local area networks.

2.2 OPERATING SYSTEM SOFTWARE

2.2.1 GENERAL REQUIREMENTS

2.2.1.1 The system software shall include an interactive application system which guides the operator through all of the inspection station functions. The application system shall provide a menu of selectable system functions. Prompting routines which are easily understood shall be used to direct the operator in a step by step manner through the completion of each system function. The routines must include input error detection and provide operator feedback for correction of invalid data entry. The structure of all furnished software shall be modular and written with attention to top down hierarchical design.

2.2.1.2 The operating system shall provide multi-level security codes (passwords) that protect the system from illegal data entry. Access to the system data base (including measurement, sensor configuration, design rule inputs and calibration data), shall require a higher level security code than access to system startup and inspection report functions.

2.2.2 SYSTEM INITIALIZATION

2.2.2.1 The system shall perform diagnostic checks on all computer and processing equipment including CPU boards, memory devices I/O interfaces (discrete, analog and serial ports), power supplies, sensors and peripheral devices (reference section 2.2.7).

2.2.2.2 A prompting routine shall be provided to direct the operator through the initialization process.

2.2.2.3 The system shall be capable of start and stop by simple key board input without repeating initialization routines. (This includes both robots and the vision system.)

2.2.3 MEASUREMENT CONFIGURATION

2.2.3.1 Product Configuration data must be stored on a non-volatile memory device that is readily available for alteration and can be loaded directly during system initialization reference section 2.2.2.

2.2.4 SYSTEM CALIBRATION

2.2.4.1 The manpower and level of technical expertise to perform system calibration must be plant personnel compatible and shall not require assistance. Calibration procedures shall be automatic and must be designed for easy implementation under the limited time constraints associated with production conditions.

2.2.4.2 Set up and system calibration data must be stored on a non-volatile memory device that is readily available for alteration, can be loaded directly during system initialization (reference section 2.2.2) and can be accessed for verification, replacement or recalibration functions.

2.2.5 MEASUREMENT DATA STORAGE

The measurement data produced by the inspection station must be stored in a data base which meets the following system requirements.

2.2.5.1 Part number, lot number and program code shall identify each part inspected. Each of these identifiers shall not exceed a 25 alpha/numeric character limit.

2.2.5.2 Date and time of system operation.

2.2.5.3 Upon completion of an inspection sequence, a data field shall be created that contains all the necessary information for report generation.

2.2.6 INSPECTION REPORTS

2.2.6.1 The generation of inspection reports for each lot of part numbers shall be sufficient to maintain report printing synchronization (real time) with each lot as it exits from the inspection cell. Reports shall also be made available if requested manually.

2.2.6.2 All reports shall be available for output in either the systems console (CRT) or printer.

2.2.6.3 Individual inspection reports shall contain at a minimum:

a. Program Code
b. Part Number
c. Lot number
d. Date and Time
e. Inspection results - Defect type, magnitude, x-y location, disposition(Accept/Reject).

2.2.7 SYSTEM DIAGNOSTICS

2.2.7.1 The objective of the system diagnostics shall be to provide the operator with automatic detection and reporting of any hardware failure, down to the board or major component level. The diagnostics should be done both at system power up (System Initialization) and during normal on-line operation or when manually requested.

2.2.7.2 System hardware diagnostics shall be provided for system initialization. The diagnostics shall verify that each major system component is operating properly prior to allowing normal on-line operation. Component failures shall be identified and reported on the system console (CRT) and printer in a fashion that is easily understood without specialized training. Reference section 2.2.2 System Initialization.

2.2.7.3 The operating system shall monitor the on-line operation and detect failure modes for all major hardware components. Component failure shall be identified and reported on the system console (CRT) and printer. Detection of component failure or power loss which may cause inaccurate measurement, shall discontinue on-line operation of the sensors, energize the system alarm annunciator and display an appropriate error message on the system console and printer.

2.2.7.4 The system shall provide on-line diagnostics which prevent the storage of invalid measurements.

2.2.8 SYSTEM UTILITIES

The following operating system utilities and features shall be provided to enable Delco Systems Operations personnel to perform troubleshooting and enhancement of the inspection system.

a. File Management
b. Editors
c. Compilers
d. Link/Loaders
e. Task Scheduling
f. Hardware Real Time Clock

2.2.9 OPERATING MODES AND CAPABILITIES

2.2.9.1 The operational sequence presented in section 2.1.3 assumes a part to be 100% inspected for both line widths and spacing as well as the listed types of defects.

2.2.9.2 Manual operator entry of part identifiers as described in section 2.2.6.3.

2.2.9.3 Manual operator prompting of on-line operation to provide the capability of inspecting without input from the inspection cell controller.

2.2.9.4 Capability of manually enabling and disabling inputs and outputs from the system console.

2.3 SYSTEM HARDWARE

2.3.1 GENERAL REQUIREMENTS

2.3.1.1 The system shall conform to Delco Systems electrical specifications and workmanship standards.

2.3.1.2 Readily available (off the shelf) materials and components shall be used wherever possible. Any single source items used in the system must be clearly identified and a statement of availability supplied.

2.3.1.3 Troubleshooting shall be facilitated by the following considerations.

a. Self-diagnostics that provide fault detection and reporting down to the major component level.
b. Easy access to all mechanical and electrical components.
c. Minimization of unique board proliferation.
d. Attention to modular design.

2.3.1.4 The system console (CRT) and printer must be mounted in enclosures which meet all of the environmental conditions stated in this specification.

2.3.1.5 All enclosures must have an automatic disconnect feature which disengages power when the internal enclosure temperature reaches the manufacturer's specified limit of the device most sensitive to elevated temperature. The power disconnection feature must be designed to provide a controlled power shut-down, which maintains the integrity of the inspection cycle that is in process at the time the power shut-down occurred.

2.3.1.6 On power up and power down conditions, all outputs shall hardware default to a safe off state and remain so until commanded differently from the controlling processor.

2.3.1.7 All DC power supply outputs shall have short circuit, over-voltage protection and adequate filtering.

2.3.1.8 There shall be an additional 120 VAC, 10 amp rated wall duplex receptacle for powering test equipment, etc., fused separately from the main circuit breakers, noise isolated from the computer/processing equipment and mounted inside the main control enclosure.

2.3.1.9 All receptacles, fuses, indicators, modules, circuit boards and test points shall be permanently labeled.

2.3.1.10 All PROM based computer/processors shall have on-line PROM checksum error detection.

2.3.1.11 Provisions shall be made to attach 4 AWG ground strap between all panels and subpanels to earth ground.

2.3.1.12 The main operating system computer must have a hardware real time clock.

2.3.2 ENVIRONMENTAL REQUIREMENTS

2.3.2.1 The inspection system must operate at full accuracy under the environmental conditions of the PWB fabrication department, including the following:

a. Ambient temperature range of 62 Deg F to 90 Deg F.
b. Humidity levels from 30% to 100% (non-condensing)
c. Airborne contaminants such as dust and oils.
d. RFI and EMI electrical noise, both conducted and radiated.

2.3.2.2 Plant power source supplying standard 120 VAC and 220 VAC.

3.0 ACCEPTANCE TESTING

The delivered machine must pass acceptance tests at the purchasers facility under the terms of the Purchase Order. Items to be used for the tests shall be from the normal production flow and typical of the current system.

The tests to be performed shall consist of comparisons between the results of machine inspection and visual examination of the product by trained personnel who currently perform that task.

Final Acceptance and payment by the contractor shall be dependent upon successful performance of these tests.

III Explanation of Technical Approach Tasks:

o Existing Method/Technical Approach Employed

After review of the many types of vision equipment available on the market, it was determined that four companies had developed equipment that could potentially fulfill the needs of this project. Extensive testing was done in an effort to determine which of the equipments was best suited for this purpose.

o Industry/vendor Survey Findings

This matrix has been formulated in order to provide a comparison between four potential suppliers of an Automatic Printed Wiring Board Machine for the Industrial Tech Mod Project #8. The information contained herein is based upon each parties responses to Delco Electronics Request for Quotation dated October 29, 1985 and Statement of Work GE-00474-85 spproved on 10/28/85.

The comment "Comply" for a specific paragraph or item means only that the potential supplier has so indicated in their response and in no way guarantees that condition exists. In the case of AEI, Inc. the indication of compliance has been entered by the undersigned, based on observed and documented performance of that equipment. This was necessary due to the lack of a detailed response from that corporation as was requested by Delco Electronics.

Point values have been assigned by "weighting" each characteristic in light of it's comparative importance. Each of the potential supplier's response is then graded by the degree of their conformance. Totaling the individual grades for each supplier then represents an overall grade for that supplier. This grade becomes a relative indication of each Suppliers conformance to Delco's needs and requirements.

The assignment of point values is based on the following definitions:

5 - Maximum importance 4 - Great importance 3 - Basic need 2 - Nice to have 1 - Minimal importance

COST COMPARISON

	ITEM	HUGHES	ADI	AEI	OPTROTEK
1.	Value: __4__ Price	Points: __1__ $440,990.00 Does not include Bar Code Labeler /Reader	Points: __4__ $378,000.00	Points: __3__ $375,000.00 Does not include Bar Code Labeler /Reader or Thermal Printer	Points: __2__ $399,900.00 Does not include Bar Code Labeler /Reader or Thermal Printer
2.	Value: __2__ Training Costs	Points: __2__ Included in base price of machine.	Points: __2__ Comply	Points: __2__ Comply	Points: __1__ Oper Training included. Maintenance personnel training costs extra.
3.	Automation and Safety System	Not Quoted	$198,000.00	Not Quoted	Not Quoted
	Value: __3__ Material handling Robot System	Points: __0__ Not Included	Points: __2__ Comply Accept, hard automation for load/unload. Operator to turn over stacks of boards	Points: __0__ Not Included	Points: __0__ Not Included
	Value: __2__ Separation of inspected hardware	Points: __0__ Not Included	Points: __1__ Comply	Points: __0__ Not Included	Points: __0__ Not Included

4	Value: _N/A_ Payment	Points: _____ Within thirty (30) days of date of invoice.	Points: _____ 50% on completion of prelim acceptance at AOI 30% on Installation at Delco 20% on completion of Acceptance at Delco	Points: _____ 40% on order 40% on runoff at AEI 20% on Acceptance at Delco	Points: _____ 10% on order 90% on Acceptance at Delco
5.	Value: __3__ Warranty	Points: __3__ Comply	Points: __3__ Comply Warranty is 12 months from date of shipment	Points: __1__ Comply With purchase of Maintenance Contract	Points: __1__ Ninety Days with purchase of Maintenance Contract
6.	Value: __3__ Freight Charges	Points: __2__ Delivery is F.O.B. Carlsbad, CA	Points: __2__ Delivery is F.O.B. Burlington, MAss	Points: __2__ No Response	Points: __1__ Delivery is F.O.B. Nes Ziona, Israel
7.	Value: __4__ Delivery Date	Points: __4__ 120 days after acceptance of order.	Points: __3__ 20 weeks after acceptance of order.	Points: __2__ Six (6) months.	Points: __4__ June 1986
8.	Value: __3__ Subcontractor advice	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
9.	Value: __3__ Applicable Documents	Points: __2__ Meets most, if not all listed GM & Delco Stds. No attempt made to verify compliance	Points: __2__ Accepted, except as noted in sect 1.2 & 2.1.2.1.1 of Attach I	Points: __1__ No Response	Points: __2__ In substantial compliance.
10.	Value: __3__ Indication of compliance or deviation from SOW requirements	Points: __3__ Comply. See comment to para 2.0 re response to GM Electrical Stds	Points: __3__ Comply AOI has responded by denoting acceptance of each line item or noting exceptions	Points: __1__ Does not Conform to Method requested by S.O.W.	Points: __3__ Comply
11.	Value: __3__ Conformance to Delco Electrical specifications and workmanship standards.	Points: __2__ See response to SOW para 2.0	Points: __2__ System Complies to Industrial Electrical Standards	Points: __2__ Comply	Points: __0__ Under examination. Will advise later.
12.	Value: __3__ Conformance with: Sound Level Spec Robotic Safety Std Basic Elec Std GM MAP	Points: __3__ See response to SOW, Para 2.0	Points: __3__ AOI equipment conforms to industry stds for safety, service & maintenance	Points: __1__ No Response	Points: __1__ Being Investigated
13.	Value: __2__ Installation Drawings	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply	Points __2__ Comply

14.	Value: __2__ Elec & Pneumatic Schematics	Points: __2__ Comply Pneumatic schematics N/A. Electricals will be provided	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply
15.	Value: __2__ Final Drawings	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply
16.	Value: __2__ Operation and Maintenance Manuals	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply
17.	Value: __3__ Ability to meet Delco PWB requirements (ES-9368, ES-11663, Mil-P-55110C)	Points: __3__ See response to SOW, para 2.0	Points: __3__ Comply as per list	Points: __3__ Comply	Points: __3__ Comply
18.	Value: __5__ Composition of Inspection Cell:	Points: __4__	Points: __5__	Points: __3__	Points: __3__
	Inspection Station Material Handling Robotics System Primary Computer System with keyboard, monitor and printer Manual Verif Station Bar Code reader Safety System Thermal Printer	Comply Not Included Comply Comply Not Included Not Included Comply	Comply Comply Comply Comply Comply Comply Comply	Comply Not Included Comply Comply Not Included Not Included Not Included	Comply Not Included Comply Comply Comply Comply Not Included
19.	Value: __4__ User Interface	Points: __2__ Comply, except Statistical Quality and trend data not now available	Points: __4__ Comply	Points: __4__ Comply	Points: __3__ Comply
20.	Value: __5__ Product types that can be inspected:	Points: __4__	Points: __5__	Points: __4__	Points: __3__
	Artwork - Silver Halide positive or negative transparencies, Diazo, Glass	Comply	Comply	Comply	Comply
	Inner Layers - Etched Copper, Photoresist on Copper	Comply	Comply	Will Conform	Comply
	PWB's - Etched Copper, Tin-lead plating, reflowed tin-lead	Tin-lead on certain substrates not easily inspected	Comply	Comply	Tin-lead plating before reflow cannot be inspected

21.	Value: __3__ Items to be inspected. (Flimsies, M/L Panels, PWB's after Lamination)	Points __2__ Comply	Points: __3__ Comply	Points __3__ Comply	Points: __2__ Comply
22	Value: __5__ Defect Types that can be detected:	Points: __5__	Points: __5__	Points __5__	Points __3__
	Line widths Line Spacing Pad sizes Annular ring dim Opens Shorts Neckdown Cracks Voids Spurious Copper Mousebites	Comply Comply Comply Comply Comply Comply Comply Comply Comply Comply Comply	Comply Comply Comply Comply Comply Comply Comply Comply Comply Comply Comply	Comply Comply Comply Comply Comply Comply Comply Comply Comply Comply Comply	Min only Min only Min only Comply Comply Comply Comply Comply Comply Comply Comply
23	Value: __3__ Delco GTR Defect Codes shall be incorporated into primary computer software	Points: __2__ Hughes defect code will be used. Comparison to Delco will be made and *differences resolved*	Points: __2__ Comply	Points: __2__ System does not use numerical code, lists defects by name	Points: __2__ Comply
24.	Value: __4__ Part Fixturing	Points: __1__ To be developed later.	Points: __4__ None Required	Points: __2__ To be developed	Points: __1__ To be developed
25	Value: __4__ Primary computer runs under a Unix-like, real-time, multi-tasking operating system such as QNX or XENIX.	Points: __3__ Primary computer is an SMS 11/23 with 512K byte memory.	Points: __4__ Comply	Points: __1__ Multibuss system built by AEI using standard cards purchased from Monolithic Systems.	Points: __1__ Functions are performed. Architecture is different
	The preferred computer for this work cell control is an IBM PC/AT.	Operating System is standard Digital RSX-11M System. (DEC LSI 11/23 Microprocessor.			
	The preferred programming language for software development within the primary computer is the "C" language.	Primary computer language is Fortran. System Algorithms written in "C" language		Programming language is Fortran.	

26	Value: __4__ The primary computer system shall be compatible with and designed to interact with the present plant computer systems (Digital Equipment Corporation VAX or PDP 11730). The inspection cell must provide data outputs to the plant system about acceptable and rejected hardware.	Points: __4__ Comply	Points: __4__ Comply	Points: __3__ Comply but will require design of interface.	Points: __2__ Can provide output to DEC VAX or PDP 1173 from VS100 PDP 11-23, not primary computer in V105.
27.	Value: __4__ System Printer is used to print Design Rules part/lot insp results and Statistical Analy- presentations.	Points: __3__ Comply A Statistical Analysis package is not part of the system	Points: __4__ Comply	Points: __4__ Comply	Points: __3__ Comply
28.	Value: __4__ Manual Verification Station X-Y table can be driven by the primary computer system down loaded from a VAX central computer system or a disc drive. Operator may step-view defects	Points: __2__ Comply Except that the X-Y table is driven by a secondary computer, normally an IBM PC	Points: __4__ Comply	Points: __3__ Data is stored on hard disc which is part of system.	Points: __3__ Comply
29.	Value: __3__ The V/R station shall present a magnified video image of the detected defect and will include a 10X microscope to be used for repair activity.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__

30	Value: __3__ The Keyboard and monitor shall be linked with software which provides a menu driven, operator friendly type of operation.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
31	Value: __4__ The data storage system must be capable of accepting the results of the activity performed at the Manual Verification Station. This data will then be available for inspection reports.	Points: __2__ The data storage portion of the central computer can accept results of Manual Verification Station activity. Software must be written.	Points: __4__ Comply	Points: __4__ Comply	Points: __3__ Comply
32.	Value: __3__ Automatic Bar Code Label attachment	Points: __0__ Not Included	Points: __3__ Comply. Labels will be manually removable	Points: __0__ Not Included	Points: __0__ Not included
33.	Value: __3__ Label will be keyed to primary computer software system	Points: __0__ Not Included	Points: __3__ Comply	Points: __0__ Not Included	Points: __0__ Not included
34	Value: __3__ Bar Code Reader	Points: __0__ Not included. The system generates a tag for the defective board.	Points: __3__ Comply	Points: __0__ Not Included	Points: __3__ Comply
35.	Value: __3__ The inspection cell shall have a safety system	Points: __2__ Do not Comply since robots are not used	Points: __2__ Comply. Included as part of automated material handling system.	Points: __2__ Comply	Points: __2__ Emergency STOP button only
36	Value: __2__ A flashing indicator light will be on when the system is operating	Points: __0__ Not Included	Points: __1__ Comply	Points: __0__ Comply	Points: __0__ Not Included

37	Value: __3__ A thermal printer shall be provided	Points: __3__ Comply	Points: __3__ Comply	Points: __0__ Not Included	Points: __0__ Not Included
38	Value: __3__ The printer shall be capable of reproducing the image present on the TV Monitor display screen.	Points: __2__ Optional Graphic Output Station reproduces the image present on the graphics monitor.	Points: __3__ Comply	Points: __0__ Not Included	Points: __0__ TV pictures stored by video recorder and reproduced on monitor
39.	SEQUENCE OF OPERATIONS				
	Value: __3__ Operator types Part number of lot of parts to be inspected. Design rules are downloaded into memory from the central database computer. Design rules should also reside on disk storage within the inspection machine primary computer system.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
	Value: __3__ First part is loaded into machine and inspection sequence is initiated.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
	Value: __1__ After the first side of the part has been inspected, the inspection sequence for the second side will be initiated.	Points: __1__ Comply	Points: __0__ Comply	Points: __1__ Comply	Points: __1__ Comply

	Value: __4 The physical order of the pieces being inspected must be maintained throughout the two inspection cycles. Bar Code labels must be applied to each defective piece. The label must carry the part number of the part as well as an arbitrary (or real) serial number identification to link the piece to the stored data.	Points: __2__ Bar code labels not used	Points: __3__ Comply	Points: __2__ Bar Code labels not used	Points: __2__ Comply
	Value: __3__ The defective items will be routed to the Manual Verification/ Repair station for final disposition.	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply
	Value: __4__ After inspection is complete, all data shall be transferred from the controller to the primary computer and an inspection report for the lot will be generated, identifying all discrepancies and providing statistical information pertaining to that lot. The quality data will also be sent to the VAX or PDP 11730 for further processing.	Points: __2__ A statistical analysis package is not provided. Data can be extracted and formatted by the user.	Points: __3__ After inspection, some data is available. After classification at the V/R station additional statistics are generated.	Points: __4__ Comply	Points: __3__ Statistical info can be generated only after defect verification step and inputting defect data by station operator
40.	Value: __4__ The system must be capable of maintaining a throughput time for a standard multi-layer inner layer panel (as used in preliminary tests) of less than one (1) minute per side.	Points: __2__ 3.0 SF - 1.0 mil 1.0 SF - 0.5 mil	Points: __4__ 6.0 SF - 1.0 mil 3.0 SF - 0.5 mil	Points: __3__ .25-3.0 SF - .3 mil	Points: __1__ 2.5 SF - 1.0 mil .84 SF - 0.5 mil

41.	Value __4__ The inspection system shall be designed to include an expansion capability. This expansion shall be accomplished through the addition of additional inspection machines linked to the same central computer and/or through expansion of the system software.	Points: __1__ System cannot be expanded. Each system requires its own central computer	Points: __4__ Comply	Points: __2__ No Response	Points: __3__ Up to two inspection units for each control unit
42.	Value: __4__ The system shall be capable of receiving and returning operational data from an intra-plant network. The electrical standard shall be IEEE-802 token passing bus or as a minimum, RS-232.	Points: __3__ Comply	Points: __3__ Comply System is capable or receiving and sending data to an intra-plant network. Stand ard will be RS-232 as a minimum.	Points: __2__ No Response	Points: __2__ The data input from an interplant network and data output as well as GM MAP protocol will be investigated.
	The protocol shall be the GM MAP standard which is based on current ISO, IEEE and NBS standards for local area networks.	No software has been written yet to accomodate the GM MAP standard which is itself not fully defined.	GM MAP protocol standards may be incorporated dependent upon configuration at time of expansion.		
43.	Value: __3__ The system shall include an interactive means of guiding the operator through the inspection station functions. The application system shall provide a menu of selectable system functions and prompting routines which will direct the operator in a step by step manner through the completion of each system function.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ No Response	Points: __3__ Comply

	The routines must include input error detection and provide operator feedback for correction of invalid data entry. The structure of all furnished software shall be modular and written with attention to top down hierarchical design.				
44.	Value: __3__ The operating system shall provide multi-level security codes (passwords) that protect the system from illegal data entry. Access to the system data base (including measurement, sensor configuration, design rule inputs and calibration data), shall require a higher level security code.	Points: __3__ Comply	Points: __3__ Comply	Points: __1__ No Response	Points: __1__ Security passwords do not exist currently. A software change can be made to meet this requirement.
45.	Value: __3__ The system shall perform diagnostic checks on all computer and processing equipment including CPU boards, memory devices, I/O interfaces, discrete, analog and serial ports), power supplies, sensors and peripheral devices.	Points: __2__ Diagnostics checks are made on most, but not all parts of the system. Except for image processor boards, diagnostics are run manually.	Points: __3__ Comply	Points: __3__ Cpmply	Points: __2__ System performs diagnostic checks for all processing equipment, memory and I/O interfaces. System does not check power supplies sensors and peripheral devices. Malfunctions of these devices can be detected by operator using builtin diagnostics and test target.
46.	Value: __3__ A prompting routine shall be provided to direct the operator through the initialization process.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points __3__ Comply

47	Value: __3__ The system shall be capable of start and stop by simple key board input without repeating initialization routines. (This includes both robots and the vision system.)	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
48.	Value: __3__ Product Configuration data must be stored on a non-volatile memory device that is readily available for alteration and can be loaded directly during system initialization.	Points: __3__ Product configuration data can be loaded after initialization sequence is complete.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
49.	Value: __4__ The manpower and level of technical expertise to perform system calibration must be plant personnel compatible and shall not require assistance.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
	Calibration procedures shall be automatic and must be designed for easy implementation under the limited time constraints associated with production conditions.	Calibration procedures are not automatic.			
50.	Value: __3__ Set up and system calibration data must be stored on a non-volatile memory device that is readily available for alteration, can be loaded directly during system initialization and can be accessed for verification, replacement or recalibration functions.	Points: __3__ Comply, but calibration is performed after initialization sequence is complete.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply

51.	MEASUREMENT DATA STORAGE				
	Value: __3__ Part number, lot number and program code shall identify each part inspected. Each of these identifiers shall not exceed a 25 alpha/numeric character limit.	Points: __3__ Comply, except that 16 characters is the alpha/numeric limit	Points: __3__ Comply	Points __3__ Comply	Points: __3__ Comply
	Value: __3__ Date and time of system operation.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
	Value: __3__ Upon completion of an inspection sequence, a data field shall be created that contains all the necessary information for report generation.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
52.	Value: __4__ The generation of inspection reports for each lot of part numbers shall be sufficient to maintain report printing synchronization (real time) with each lot as it exits from the inspection cell. Reports shall also be made available if requested manually.	Points: __2__ Raw data is available to create reports. Software does not include a report generator.	Points: __4__ Comply	Points: __4__ Comply	Points: __2__ Reports are made by manual request via supvr terminal unit See para 3.4 in VS100 Product Description
53.	Value: __4__ All reports shall be available for output in either the systems console (CRT) or printer.	Points: __2__ Report software not currently available	Points: __4__ Comply	Points: __4__ Comply	Points: __2__ Comply

54.	Value: __4__ Individual inspection reports shall contain at a minimum: a. Program Code b. Part Number c. Lot number d. Date and Time e. Inspection results - Defect type, magnitude, x-y location, disposition (Accept/Reject).	Points: __3__ Report software not currently available.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
55.	Value: __3__ The objective of the system diagnostics shall be to provide the operator with automatic detection and reporting of any hardware failure, down to the board or major component level. The diagnostics should be done both at system power up (System Initialization) and during normal on-line operation or when manually requested.	Points: __2__ Image processors are continually checked by sub-host processor. This is automatic without operator intervention. Diagnostics for rest of the system must be requested manually.	Points: __2__ System diagnostics are run when system is turned on. Inspection sytem diagnostics are run on request. System can be configured to do these with system turn-on but not recommended due to time required.	Points: __2__ Complies	Points: __2__ The system includes diagnostics for maintenance personnel and for enabling an operator to define malfunctions to a service engineer. It does not have automatic diagnostics except for selftesting of CPU's and communications.
56.	Value: __3__ Diagnostics shall be provided for at initialization. They shall verify major components are operating properly prior to allowing operation. Failures shall be identified and reported on the system console (CRT)	Points: __2__ Diagnostics not engaged at initialization. Component fails should be recognized by experienced operator but not reported on CRT.	Points: __2__ See 2.2.7.1	Points: __2__ Comply	Points: __2__ See 2.2.7.1

57.	Value: __3__ The system shall monitor the on-line operation and detect failures of major components and report on the CRT & printer. Failures which may cause innacurate measurement should discontinue operation and initiate the alarm sequence.	Points: __2__ Image processors are continually checked by sub-host processor and automatically removed if failure occurs. Fail not reported on CRT. Failure of certain other components or power loss does not necessarilly give an indication of failure.	Points: __2__ See 2.2.7.1	Points: __2__ Comply	Points: __2__ See 2.2.7.1
58.	Value: __3__ The system shall provide on-line diagnostics which prevent the storage of invalid measurements.	Points: __2__ Comply with regard to image processing boards.	Points: __2__ See 2.2.7.1	Points: __2__ Comply	Points: __2__ See 2.2.7.1
59.	Value: __4__ The following operating system utilities and features shall be provided to enable Delco Systems Operations personnel to perform troubleshooting and enhancement of the inspection system.	Points: __3__	Points: __4__	Points: __2__	Points: __0__
	a. File Management b. Editors c. Compilers d. Link/Loaders e. Task Scheduling f. Hardware Real Time Clock	Comply Comply Not included Comply Comply Not included	Comply Comply Comply Comply Comply Comply	No Response No Response No Response No Response No Response No Response	Accessed by Optrotek Engineers only. Not provided to customers.
60	Value: __4__ The operational sequence presented previously assumes a part to be 100% inspected for both line widths and spacing as well as the listed types of defects.	Points: __4__ Comply	Points: __4__ Comply	Points: __4__ Comply	Points: __4__ Comply

61.	Value: __3__ Manual operator entry of part identifiers as described in section 2.2.6.3. (Program Code, P/N, Lot#, Date/Time, Insp results)	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
62.	Value: __3__ Manual operator prompting of on-line operation to provide the capability of inspecting without input from the inspection cell controller.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ After initial part number is set up, later panels are inspected by calling out parameters from an internal database
63.	Value: __3__ Capability of manually enabling and disabling inputs and outputs from the system console.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
64.	Value: __3__ Readily available materials and components shall be used wherever possible. Single source items must be identified and a statement of availability supplied.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
65.	Value: __3__ Troubleshooting shall be facilitated by the following:	Points: __3__	Points: __3__ Trouble shooting is facilitated by the following:	Points: __3__	Points: __2__
	a. Self-diagnostics that provide fault detection and reporting down to the major component level.	Comply	Comply Self-diagnostics provide trouble shooting capability to sub-assy level such as camera or logic card	Comply	Does not comply
	b. Easy access to all mechanical and electrical components.	Comply	Comply	No Response	Comply

	c. Minimization of unique board proliferation	Comply	Comply	No Response	Comply
	d Attention to modular design.	Comply	Comply	No Response	Comply
66	Value: __2__ The system console (CRT) and printer enclosures must meet all of the environ-conditions stated in this specification.	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ No Response	Points: __2__ Environmental requirements described in para 2.3.2.1
67.	Value: __3__ Enclosures must have an overtemperature disconnect feature designed to provide a controlled shut-down, maintaining the integrity of the inspection cycle that is in process at the time of the shut-down.	Points: __0__ Do not Comply	Points: __3__ Comply	Points: __0__ Does not comply	Points: __0__ System does not have automatic disconnect. Can be designed in as part of robotics system.
68.	Value: __3__ At power up and power down, all outputs shall default to a safe off state and remain until commanded by the controlling processor.	Points: __0__ Do not Comply	Points: __3__ Comply	Points: __0__ No Response	Points: __3__ Comply
69.	Value: __3__ All DC power supply outputs shall have short circuit, over-voltage protection and adequate fil-tering.	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply	Points: __3__ Comply
70.	Value: __2__ There shall be a 120 VAC, 10 amp wall duplex receptacle mounted inside the main control enclo-sure.	Points: __2__ Comply	Points: __2__ Comply	Points: __2__ Comply	Points: __0__ Does not currently have. Need more detail on this requirement.

71.	Value: __3__ All receptacles, fuses, indicators, modules, circuit boards and test points shall be permanently labeled.	Points: __3__ Comply	Points: __3__ Comply	Points __3__ Comply	Points __3__ Comply
72.	Value: __3__ All PROM based computer/processors shall have on-line PROM checksum error detection.	Points: __0__ Do not Comply	Points: __3__ Comply	Points: __0__ No Response	Points: __3__ System does have on-line prom checksum error
73.	Value: __3__ There shall be a #4 AWG ground strap between all panels and sub-panels to earth ground.	Points: __2__ Comply, except that strap is #10 AWG	Points: __3__ Comply	Points: __2__ Comply	Points: __3__ Comply
74.	Value: __4__ The main operating system computer must have a hardware real time clock.	Points: __0__ Do not Comply	Points: __4__ Comply	Points: __0__ Does not comply	Points: __4__ Comply
75.	Value: __4__ System must operate at full accuracy under the following environmental conditions:	Points. __2__	Points: __2__	Points: __2__	Points: __2__
	a. Ambient temperature range of 62 to 90 Deg F.	Does not Comply 60-80 Deg F.	Comply 45-90 Deg F.	Does not Comply 15-30 Deg C. (59-86 Deg F.)	Does not Comply 60-76 Deg F.
	b. Humidity levels from 30% to 100% (non-condensing)	Does not Comply 30-70% Humidity	Does not Comply 20-80% Humidity	Does not Comply 30-80% Humidity	Does not comply 40-60% Humidity
	c. Airborne contaminants such as dust and oils.	Excessive airborne contaminants could cause false alarms	Inspection will operate in a dust and oil environment. Contaminants will be reported as defects.	No Response	Airborne dust or dirt particles can cause shorts or accelerated wear of moving mechanical devices Dust may show as defect. System not effected by regular RFI and EMI noises
	d. RFI and EMI electrical noise, both conducted and radiated.	Excessive RFI and EMI could cause processing errors.	System meets FCC Class A inteference requirements in industrial environment	No Response	

76	Value: __3__ Plant power source supplying standard 120 VAC and 220 VAC	Points: __3__ Comply	Points: __3__ Comply	Points __3__ Comply	Points __3__ See para 4 of Site preparation document
77.	Value: __4__ The delivered machine must pass acceptance tests at the purchasers facility under the terms of the Purchase Order.	Points: __4__ Comply	Points: __4__ Comply ATP shall be mutually agreed upon between ADI & Delco prior to PO acceptance.	Points __4__ Comply	Points: __4__ Comply
	Items to be used for the tests shall be from the normal production flow and typical of the current system.	Comply	Comply	Comply	Comply
	The tests to be performed shall consist of comparisons between the results of machine inspection and visual examination of the product by trained personnel who currently perform that task.	Comply	Comply	Comply	Comply
	Final Acceptance and payment by the contractor shall be dependent upon successful performance of these tests.	Comply	Preliminary Acceptance at ADI shall be limited to five working days. Final Acceptance at Delco shall begin within five days after installation completion and shall be limited to five days.	Comply	Comply
Total Value: _270_		Total Points: 192_	Total Points: _248_	Total Points: _189_	Total Points: _182_

o Preliminary Cost Benefit Analysis

1. *Reduction of Scrapped material during fabrication process*

Annual scrap costs 1984 (Feb-Dec) = $215,665.64
Average monthly scrap costs 1984 = 215,665.64/11 = $19,605.97

Annual scrap costs 1985 (Jan-Dec) = $251,203.90
Average monthly scrap costs 1985 = 251,203.90/12 = $20,933.66

Annual scrap costs 1986 (Jan-May) = $125,624.70
Average monthly scrap costs 1986 = 125,624.70/5 = $25,124.94

Total $65,664.57

Average monthly scrap costs $21,888.19

Average Annual Scrap Costs = $21,888.19 x 12 = $262,658.28
X .20

Anticipated scrap reduction of 20% = $52,531.66

- o Improved handling
- o Vision inspection of artwork
- o Process information feedback

2. Reduction of labor costs for repairs due to PWB opens & shorts.

Open circuits detected by Ditmco Test during 1985 = 3279

Recording & Logging	5 min x 3279 = 16395/60	= 273.3 Hrs
MRBR processing	15 min x 3279 = 49185/60	= 819.8 Hrs
Red Wire repair	10 min x 3279 = 32790/60	= 546.5 Hrs
Inspection of repair	1 min x 3279 = 3279/60	= 54.7 Hrs
	Total	1694.3 Hrs

1694.3 Hrs X $20.20 = $34,224.86

Shorted circuits detected by Ditmco Test during 1985 = 358

Recording & Logging	5 min x 358 = 1790/60	= 29.8 Hrs
Rework	40 min x 358 = 14320/60	= 238.7 Hrs
Inspection of Rework	1 min x 358 = 358/60	= 6.0 Hrs
	Total	274.5 Hrs

274.5 Hrs X $20.20 = $5544.90

Total Rework Costs $39,769.76

Reduction of rework possible due to detection of open and short conditions prior to lamination of the PWB.

3. Reduction in Inspection labor by 40%.

   The current work force of nine (9) personnel would be reduced to five (5), resulting in a savings of four (4) persons.

   4 people X 40 Hrs/wk X 52 wks/yr = 8,320 Hrs/Year

   8,320 Hrs X $20.20/Hr = $168,064.00

4. Scrap avoidance for CCA's with internal shorts and/or opens detected during card test operations.

   Scrap costs for this cause in 1985 were $31,770.00

5. Other Cost Savings:

   - o Inventory Reduction
   - o Automatic collection of Defect & Payroll Data
   - o Elimination of Ditmco Testing
   - o Reduced storage area requirements due to improved throughput times
   - o Overall Quality improvement

6. Summary

Anticipated scrap reduction of 20%	$52,531.66
Total Rework Costs	39,769.76
Inspection Labor reduction	168,064.00
Higher Assembly Scrap	31,770.00
Total Annual Cost Reduction	$292,135.42

7. Investment Payback

   Cost of Equipment $400,000.00

   Payback in Years = Cost of Equipment/Annual Cost Reduction

   $400,000.00/$292,135.42 = 1.37 Years

o Equipment Alternatives

In addition to the four suppliers in the final competition, the following lists other companies that were investigated to determine if their equipment might be capable of meeting our requirements:

* Applied Intelligent Systems, Ann Arbor, MI
  Anorad Corporation, Hauppauge, NY
* Automation Tooling Systems, Kitchener, Ontario
  Automatix Inc, Burlington, MA
  Cambridge Robotics, Watertown, MA
  Consolidated Controls, Danbury, CN
  Everett/Charles, Rancho Cucamonga, CA
  HAM Industries Inc, Macedonia, OH
  Image Technology, Carpentersville, IL
  McBain Instruments Inc, Chatsworth, CA
  MICROVU, Santa Ana, CA
  Operations Technology Inc, Blairstown, NJ
  Precision Industries Inc, Cleveland, OH
  PROJECTINA Ltd, Heerbrugg, Switzerland
  TESTERION Inc, Cucamonga, CA
  View Engineering, Chatsworth, CA

The companies indicated by "*" are ones which were given some serious attention, but were eliminated in favor of the four final contendors. These two were systems houses and would have had to integrate the various equipments required to "develop" an inspection cell. The prefered solution was to utilize a proven, standalone system which several companies had developed as their sole product line. The remaining companies on the list were eliminated due to product line maturity, speed, accuracy, and the "perceived ability to support their product in the future".

o Implementation Plan/Results

Plans are currently being formulated for the installation of a "computer-type" room with controlled temperature and humidity as well as a filtered air system. With this type of environment "false alarms" caused by airborne contaminants will be minimized, if not eliminated.

The results of implementation of this equipment in the manufacturing environment will be available once the installation is completed.

IV Equipment/Machining Specifications

The following is a comparison of the technical characteristics of the equipments available from the four finalists in this quest.

AUTOMATIC PWB INSPECTION MACHINE CHARACTERISTICS MATRIX

Feature	Automation Eng Inc	ITEK Optical Systems	Optrotek, Inc	Hughes Aircraft Co.
Inspected Area	24" x 24"	18" x 27"	18" x 24"	24" x 28"
Product Features				
Artwork	Silver Halide Pos or neg trans-parencies Diazo	Silver Halide Diazo Glass P.A.C.	Silver Halide	Silver Halide Diazo Film, Pos or Neg Glass
Inner Layers	Etched copper After tin-lead reflow	Etched copper Photoresist on Copper	Etched copper Photoresist on Copper	Etched Copper Oxide Coated Photoresist on Copper
PWB's	Etched copper After tin-lead reflow	Etched copper	Etched copper	Etched Copper
Pad Size	at 0.32 mil resolution .010 in min .100 in max (up to 6)			at 0.3 mil resolution .020 in min .040 in max (Need more memory to accomplish this)
		at 0.50 mil resolution Any size	at 0.50 mil resolution _____ _____	at 0.5 mil resolution .030 in max .060 in max
		at 1.0 mil resolution Any size	at 1.0 mil resolution _____ _____	at 1.0 mil resolution .040 in min .080 max
Line Width & Spacing	at 0.32 mil resolution .0035 in minimum .100 in maximum			at 0.3 mil resolution .003 in min .020 in max
		at 0.50 mil resolution .003 in minimum .012 in maximum	at 0.50 mil resolution .004 in minimum _____	at 0.50 mil resolution .004 in min .024 in max
		at 1.0 mil resolution .006 in minimum .024 in maximum	at 1.0 mil resolution .008 in minimum _____	at 1.0 mil resolution .006 in min .035 in max
Annular Rings	Yes	Yes	Yes	Yes

Hole Sizes	Yes	No	No	Yes
Max Resolution	0.32 mil	0.50 mil	0.50 mil	0.30 mil
Detected Flaws	Six (6) Sizes Min conductor spacing Min/Max conductor width Cracks & Voids Rough edges Opens Shorts Spurious Copper Mousebites Annular rings Hole sizes	Four (4) Sizes Min conductor spacing Min/Max conductor width Cracks & Voids Rough edges Opens Shorts Spurious Copper Mousebites Annular rings	One (1) Size Min conductor spacing Min conductor width Cracks & Voids Rough edges Opens Shorts Spurious Copper Mousebites Annular rings	Three (3) Sizes Min conductor spacing Min conductor width Cracks & Voids Opens Shorts Spurious Copper Mousebites Annular rings Hole sizes
Inspection Speed	0.32 mils Resolution 2.5-.25 SF/min			0.30 mil Resolution 0.3 SF/Min
		0.50 mil Resolution 2.0 LF/Min x "N" width	0.50 mil Resolution 0.84 SF/Min	0.50 mil Resolution 1.0 SF/Min
		1.0 mil Resolution 4.0 LF/Min x "N" width	1.0 mil Resolution 2.50 SF/Min	1.0 mil Resolution 3.0 SF/Min
Load/Unload Cycle Time	Approx 30 Sec	Approx 12 Sec	Approx 30 Sec	Approx 20 Sec
Output	Video Display of flaws Printout Design Rules Printout XY Coordinates Classify Fault Printout Fault Class Store data Provide average (per panel or per batch) line widths for each class.	Video Display of flaws Printout Design Rules Printout XY Coordinates Printout Sensor ID Store data Classify Defects by panel and Batch (Using off-line Manual Verification Station)	Video Display of flaws Printout Design Rules Printout XY Coordinates Store data (Using off-line Manual Verification station) Ink mark flaw location	Digitized Display of flaws Printout XY Coordinates Printout Detector # Store Data (Using off-line Manual Verification Station) Ink mark flaw location
Space Requirements				
Insp Station	45 SF	40 SF	44 SF	50 SF
Verif Station	Optional	20 SF	20 SF	Options available
Interface	RS-232 serial interface port	RS-232 serial interface port	———	RS-232 serial interface port(9600 baud)
Power Requirements	Single phase, 60 Hz, 115/230 volts @ 30 Amps	115V, 60 Hz, @30 Amps Single Phase	Two 3-phase, 115V, 60 Hz, 4KVA supplies	208 VAC, 3 phase, 5 wire, 50/60 Hz(20 Amps/phase max dual drops required)
Self-test & Diagnostics	Yes	Yes	No	Yes

Operating Environment	Temp 15-30 deg C. Rel Humidity 30-80%	Temp 45-90 deg F. Rel Humidity 20-80%	Temp 60-85 deg F. Rel Humidity 20-80%	Temp 60-80 deg F. Rel Humidity 30-70%
Statistical Analysis	Statistical record(For each panel/class) Avg trace widths Avg hole diameter Avg trace width of small lines. Avg annular ring spacing.	Defect Analysis by board and/or by batch/lot and histogram analysis.	Available as extra feature with Computer Controller.	None. Software could be generated to provide some.
Cost	All four units cost between $300-400K, depending upon extra features ordered.			

V Measurement Procedures, Specifications and Test Results

All equipments were tested using product from the Delco Electronics PWB Fabrication department. The same items were tested on each suppliers equipment. Tests were extensive, with the primary goals being accuracy and repeatability with minimal "false alarm" rates.

VI Problems Encountered and How Resolved

The only real problem encountered in the search for suitable equipment for this project dealt with the development of the technology itself. During the three years involved the technology underwent many changes and is still changing today. Comparisons of different equipments had to be made within a reasonable time span of each other in order to have a meaningful relationship. Changes in the technology primarily occured in the machine vision/processing area. In the last three years vision has advanced from 64 levels of grey scale with binary image digitizing to 256 levels of true grey scale. This has been accomplished due to the availability of faster computers and advanced image processing algorythms. These advances have allowed systems to operate much faster and more accurately and will continue to do so even in the future.

VII Areas for Future Concern/Development

Consideration has been given to the tasks of integrating the PWB inspection cell with an automated material handling system, Computer Integrated Manufacturing (CIM) system, and Manufacturing Information System(MIS). Due to the higher than anticipated costs ($100,000 over run) associated with the AOI equipment and installation, aquisition of material handling equipment has been delayed. The delivered system presently does have the flexability to operate with a material handling system and computer access for CIM and MIS does exist. Delco's long range manufacturing upgrade plan does include these options (CIM, MIS) and when available will be linked to the PWB inspection cell.

VIII Identification of Equipment/Tooling Needs

At present there is no need for special tooling for use of this equipment. Development of specialized material handling containers could evolve from experience gained in the use of the equipment.

IX Prototype Design Findings

At the completion of all testing and evaluation ADI Inc (Formerly ITEK) was chosen as the supplier whose equipment most completely filled the needs of Delco Electronics. A Purchase Order for one (1) Multimedia Inspection System with Bar Code Labeler and two (2) Verification/Repair Stations was presented to ADI on August 28, 1986. (See Figures 1 and 2)

X IDEF Models

See Figures 3 and 4.

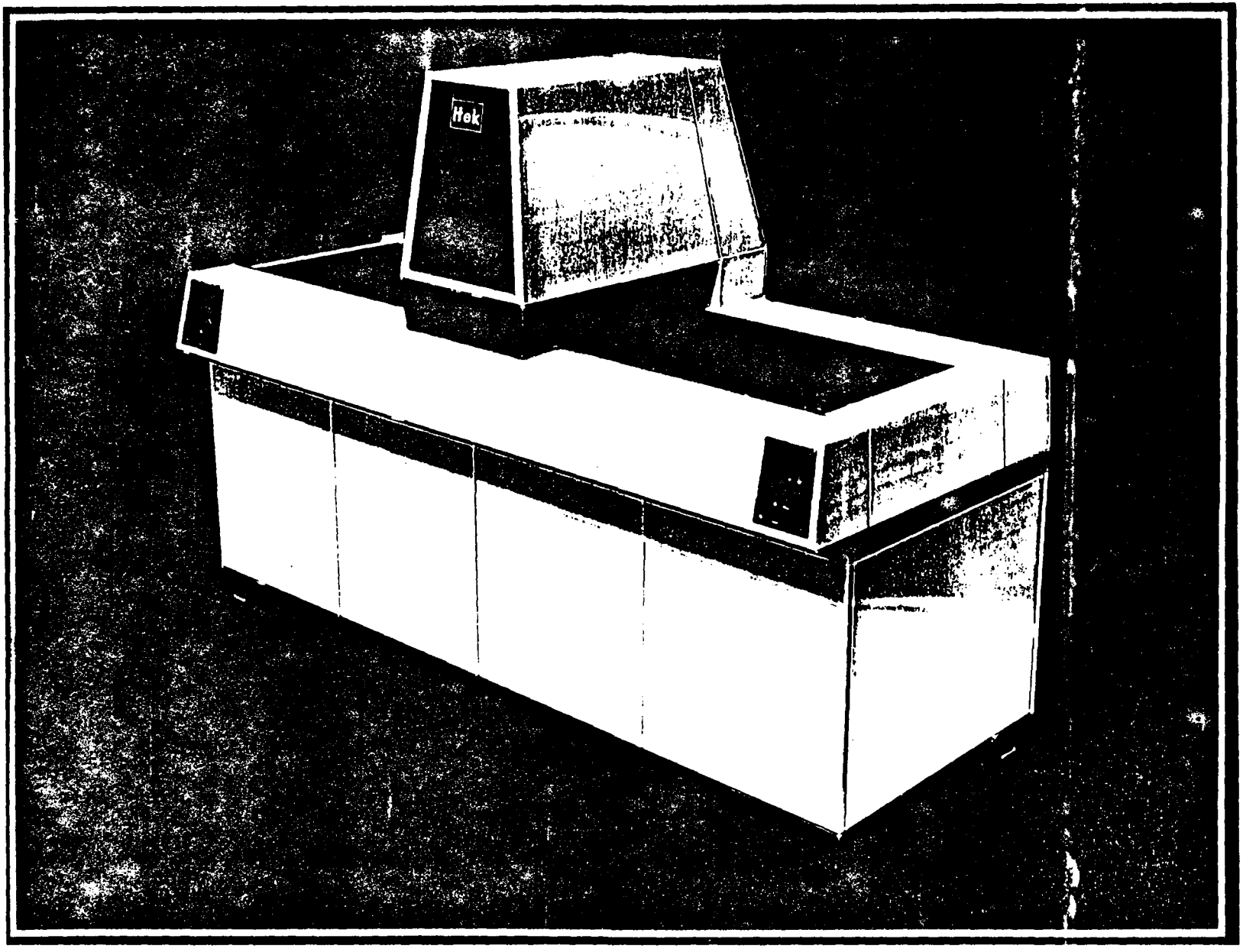
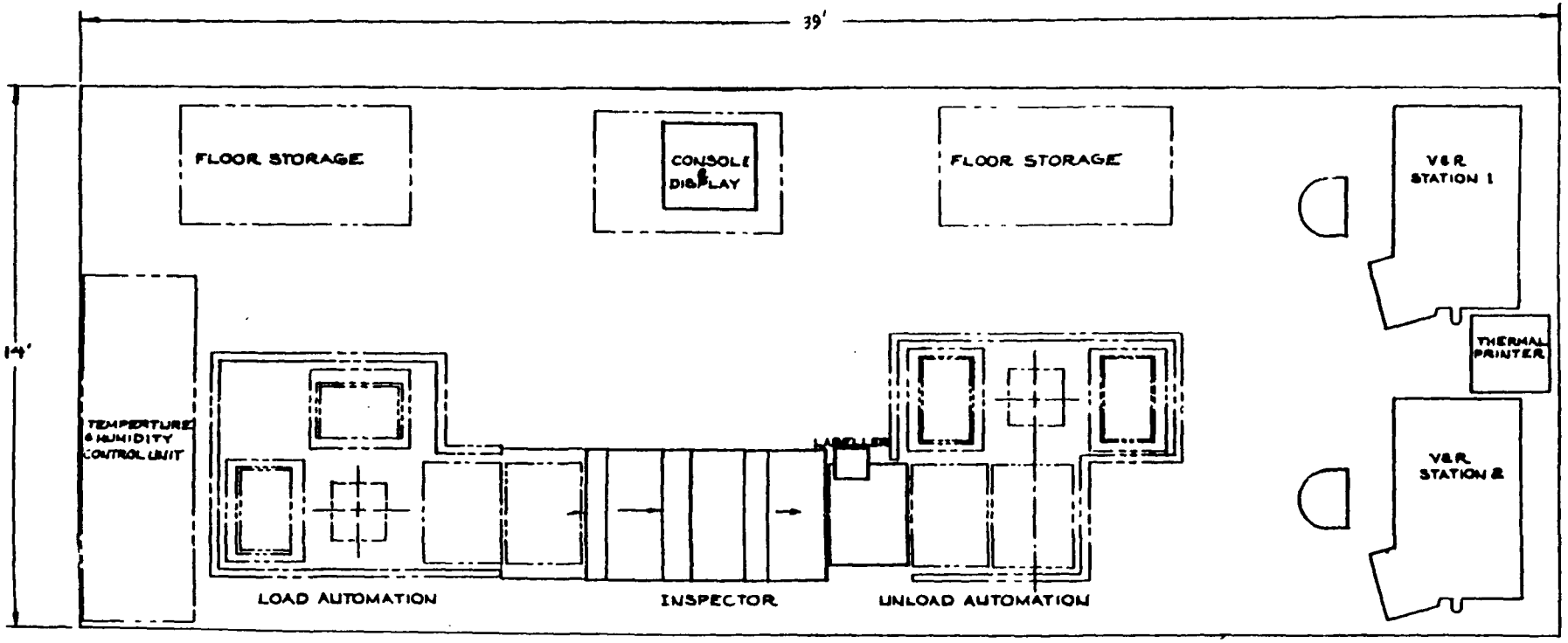


FIGURE 1. PWB AUTOMATIC INSPECTION MACHINE



POWER REQUIREMENTS:

INSPECTOR:
(1) 115 VOLTS 30A
(2) 115 VOLTS 20A
(1) 115 VOLTS 10A

V&R (PER STA.):
(1) 115 VOLTS 10A

LABELLER:
(1) 110 VOLTS 3A

CONSOLE & DISPLAY:
(1) 110 VOLTS 1.5A (CONSOLE
(1) 110 VOLTS 2A (DISPLAY

FIGURE 2. EQUIPMENT INSTALLATION/FLOOR LAYOUT

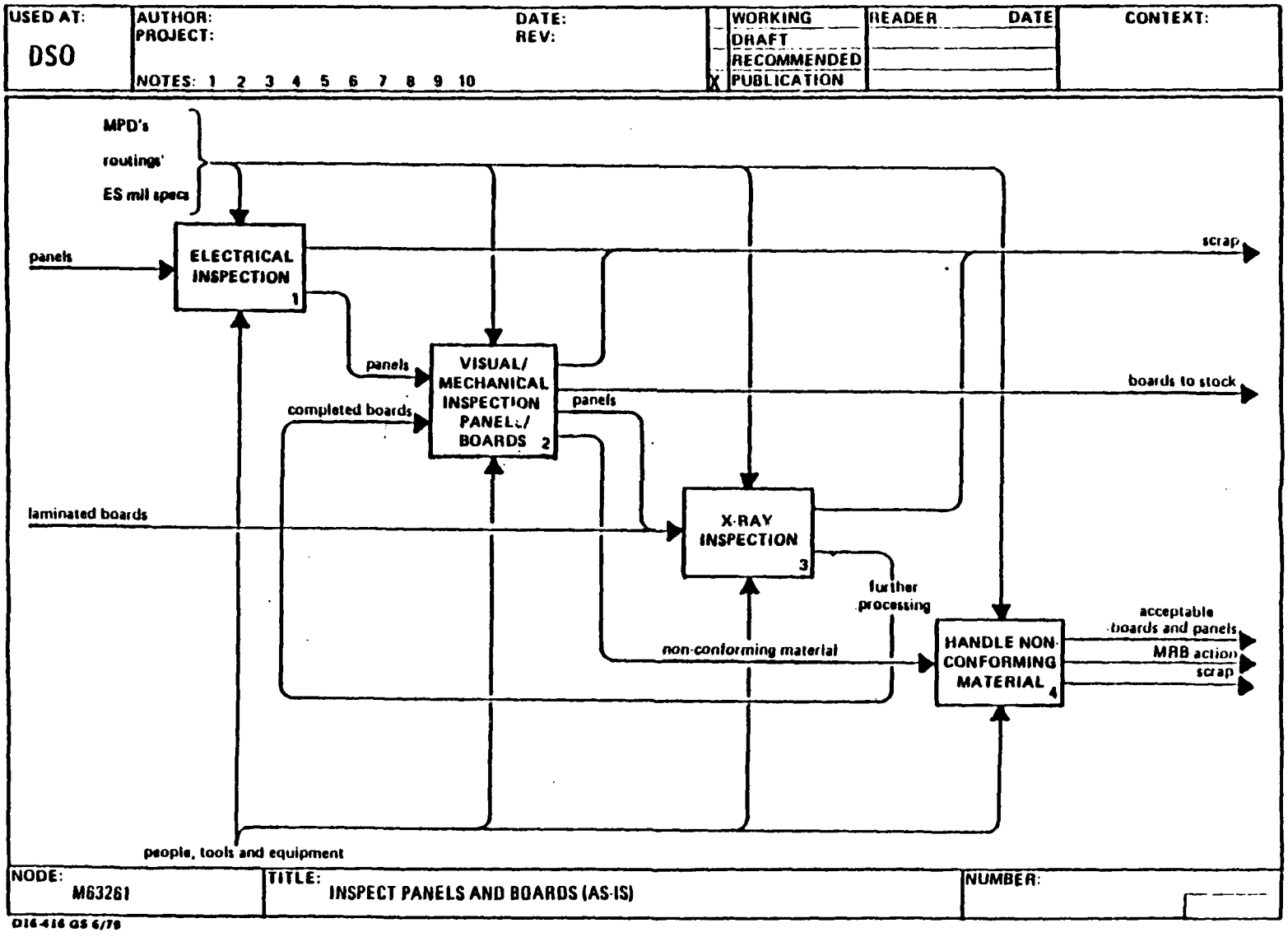
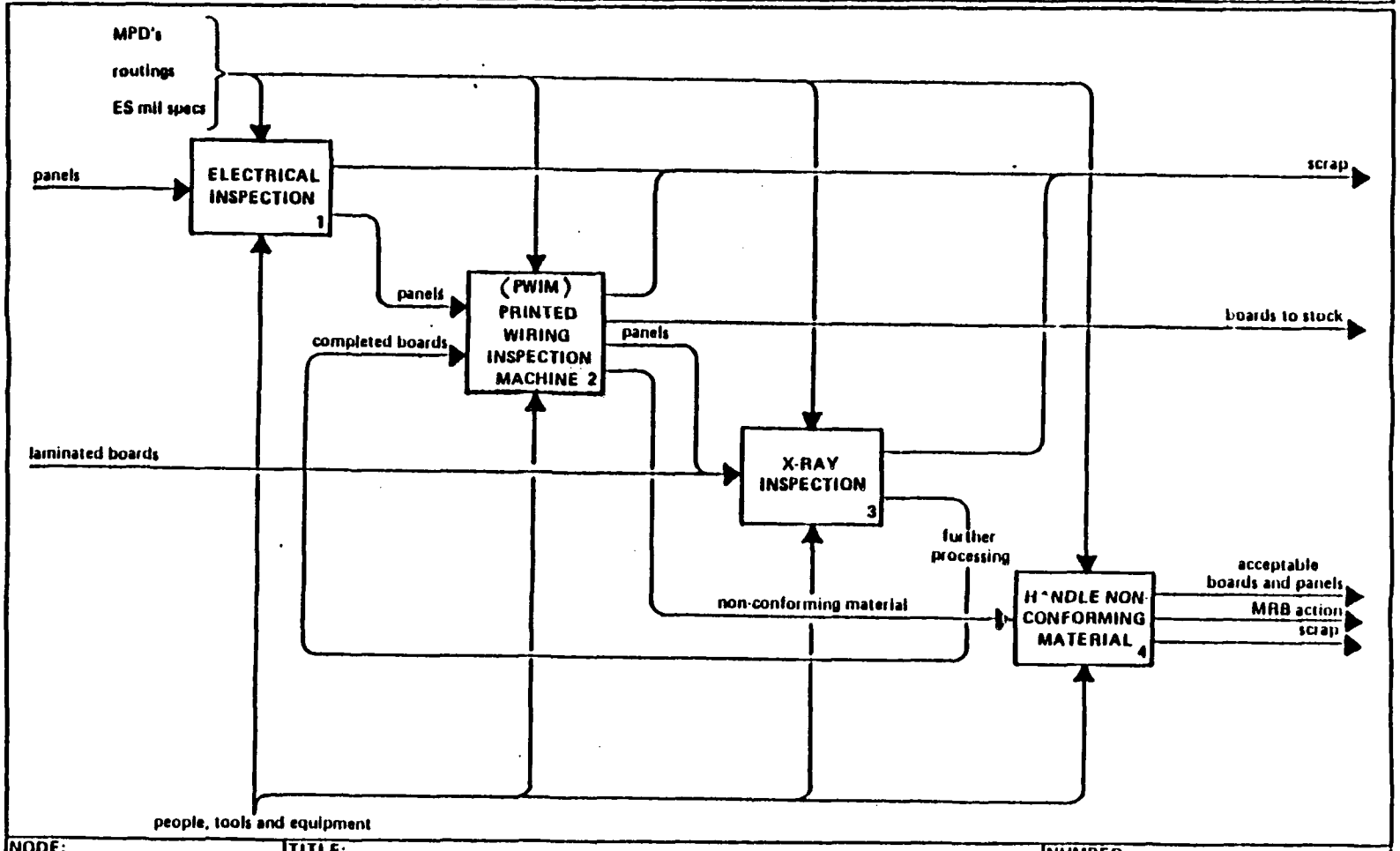

USED AT:
DSO
AUTHOR:
PROJECT:
DATE:
REV:
NOTES: 1 2 3 4 5 6 7 8 9 10
WORKING
DRAFT
RECOMMENDED
X PUBLICATION
HEADER
DATE
CONTEXT:
MPD's
routings'
ES mil specs
panels
ELECTRICAL INSPECTION 1
scrap
panels
VISUAL/ MECHANICAL INSPECTION PANELS/ BOARDS 2
boards to stock
completed boards
panels
laminated boards
X-RAY INSPECTION 3
further processing
non-conforming material
HANDLE NON-CONFORMING MATERIAL 4
acceptable boards and panels
MRB action
scrap
people, tools and equipment
NODE:
M63261
TITLE:
INSPECT PANELS AND BOARDS (AS-IS)
NUMBER:
D16-416 GS 6/79

FIGURE 3

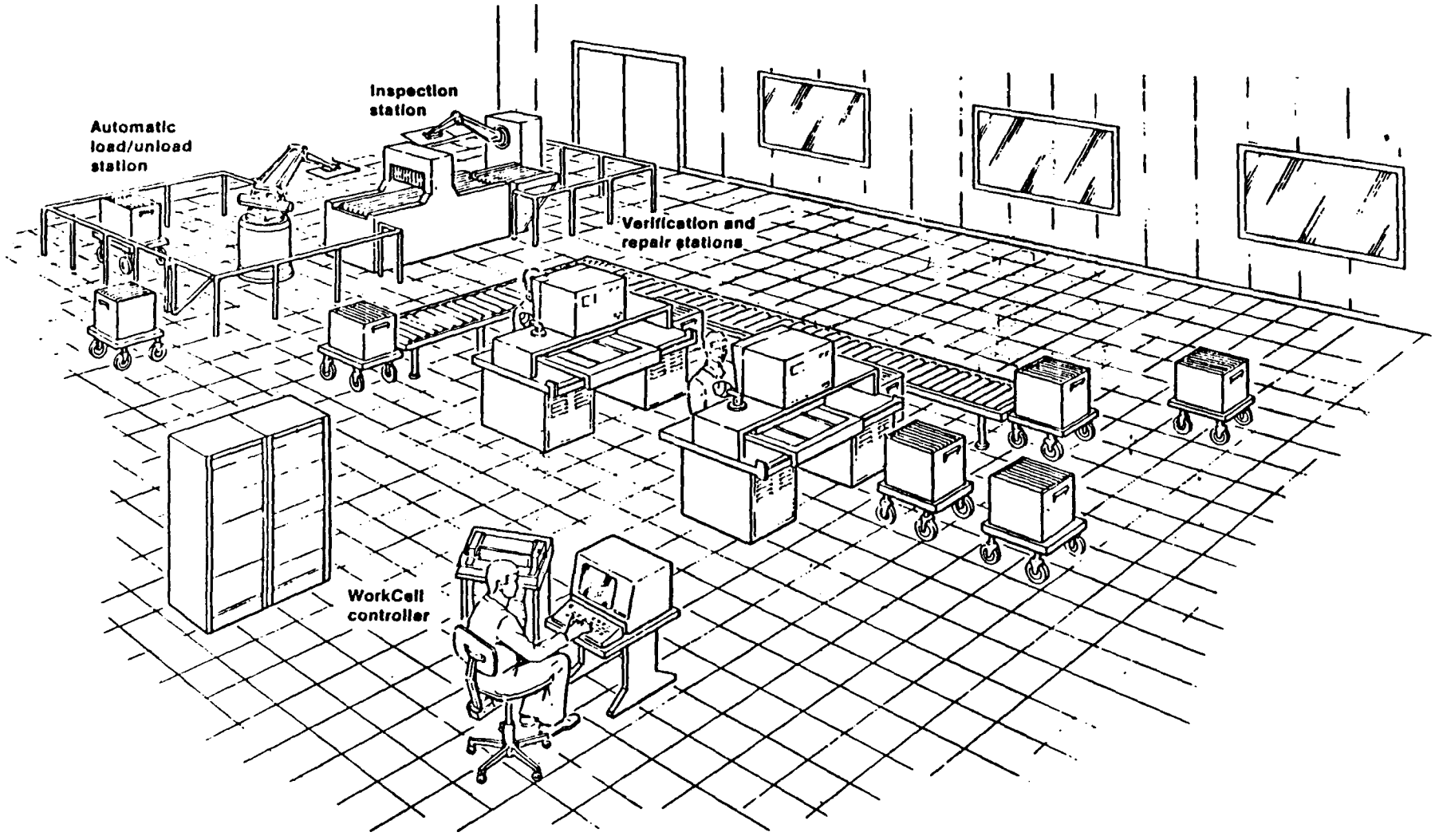
USED AT:	AUTHOR:	DATE:		WORKING	READER	DATE	CONTEXT:
DSO	PROJECT:	REV:		DRAFT			
	NOTES: 1 2 3 4 5 6 7 8 9 10			RECOMMENDED			
			X	PUBLICATION			



NODE:	TITLE:	NUMBER:
M63261	INSPECT PANELS AND BOARDS (TO-BE)	

D16-416 QS 6/79

FIGURE 4


Automatic
load/unload
station
Inspection
station
Verification and
repair stations
WorkCell
controller

WorkCell

04-Nov-80

CASH FLOW EVALUATION ($000,S OMITTED)

10-RGG-12/ITMOSMKE

PROJECT NO.: 098
PROJECT NAME: IN-CIRCUIT TESTER - MILWAUKEE

YEAR:	1984 (0)	1985 (1)	1986 (2)	1987 (3)	1988 (4)	1989 (5)	1990 (6)	1991 (7)	1992 (8)	1993 (9)	1994 (10)	1995 (11)
INVESTMENT DATA:												
DEVELOPMENT *	(1)	4	21	30								
FACILITIES *			494	17	9							
TOOLING *			39	15								
TOTAL	(1)	4	554	62	9	0	0	0	0	0	0	0
PROFIT AND CASH FLOW DATA:												
GROSS SAVINGS *			0	34	183	284	738	1,598	2,196	1,792	1,900	2,013
LESS:												
DEPRECIATION FACILITIES		0	0	99	161	126	86	44	3	1	0	0
TOOLING		0	0	13	23	15	3	0	0	0	0	0
TOTAL	0	0	0	112	184	141	89	44	3	1	0	0
PROJECT CHARGES TO OPERATIONS *	0	0	0	2	2	2	2	3	3	3	3	3
TOTAL EXPENSES	0	0	0	114	186	143	92	47	5	4	3	3
NET SAVINGS BEFORE TAXES	0	0	0	(80)	(3)	141	646	1,551	2,191	1,788	1,897	2,010
NET SAVINGS AFTER TAXES (TAX @ .37)	0	0	0	(50)	(2)	89	407	977	1,380	1,127	1,195	1,266
ADD DEPRECIATION	0	0	0	112	184	141	89	44	3	1	0	0
CASH FLOW FROM OPERATIONS	0	0	0	61	182	230	496	1,022	1,383	1,127	1,195	1,266
INVESTMENT CREDIT		0	0	0	3	1	0	0	0	0	0	0
NET CASH FLOW	1	(4)	(554)	(1)	176	231	496	1,022	1,383	1,127	1,195	1,266
CUMULATIVE CASH FLOW	1	(3)	(557)	(558)	(382)	(151)	345	1,367	2,750	3,877	5,072	6,338

PAYBACK AND RETURN ON INVESTMENT:
PAYBACK 4.3 YRS.
RETURN ON INVESTMENT (DISCOUNTED CASH FLOW) 0.544184

* INPUT BY REQUESTOR

DEPRECIATION TABLE:
(POST 1985)

EQUIPMENT 5 YEAR	TOOLING 3 YEAR	YEAR NO.
0.20	0.33	1
0.32	0.45	2
0.24	0.22	3
0.16		4
0.08		5

	TOTAL
	520
	54
	574